With the Author's Compliments.

ON THE CHRONIC BLOCK-MOVEMEMENTS IN THE KYOTO-OSAKA DISTRICT.

By

A. Imamura.

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5. *On the Chronic Block-Movements in the Kyoto-Osaka District.*

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[With 4 text-figures.]

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Formerly, the prevailing view was that the course of the River Yodo, might be a seismogenic line, but it was later abandoned. According to Dr. T. Ogawa, Dr. S. Nakamura, and others, the active tectonic lines in this district, as in others, seem to be indicated by certain meridional lines such as the Yamazaki fault, the Higasiyama line and the Daigo line. These tectonic lines may indeed be *geologically active*. I shall deal here with three

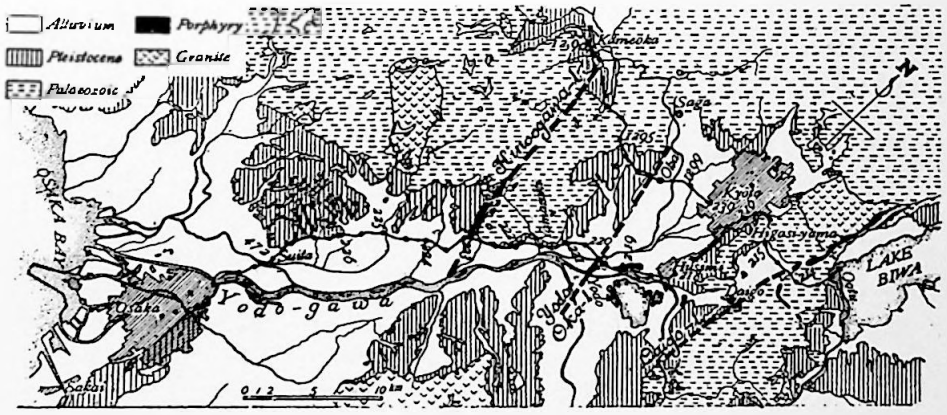

Fig. 1.

that are *active at present*—the Hinoogawa line, the Yodo-Oka line and the Daigo line. Thanks to the whole-hearted support of the Military Land Survey Department, precise levellings were repeatedly carried out along the routes, one linking Suita near Osaka with Ootu via Kyoto and the other linking Kyoto with Kameoka (Tables I and II). The results of these surveys having been placed at my disposal through the courtesy of the staff of the

said Department, it is now possible for me to briefly report on the results of my studies in connexion with the present problem.

Table I.

B. M. No.	1897, I-III −1885, IX-XV	1899, X-XIII −1897, I-III	1928, XII −1899, X-XIII
	mm	mm	mm
1300 (Ootu)	0.0	0.0	0.0
213	0.0	0.0	+ 13.3
213.1		+ 3.6	+ 21.4
214	+ 7.9	− 7.6	+ 48.7
214.1		−12.7	+ 37.8
215	+11.4	− 8.1	+ 33.6
215.1		− 7.3	+ 18.0
216	+11.4	− 6.5	+ 8.3
216.1		− 4.3	+ 8.3
217	+ 9.3	− 6.7	− 5.0
217.1		− 2.5	− 23.9
218 (Husimi)	+ 2.2	− 5.9	− 26.6
218.1	*−13.0	− 7.9	− 72.9
219	−28.3	− 5.9	−100.1
219.1 (Noso)	†−38.4	− 6.6	−218.7
220	−12.5	− 5.4	
221	+ 4.0	− 8.5	+ 17.4
221.1		−10.2	+ 35.9
222 (Simamoto)	+ 9.4	−12.3	
222.1		−12.2	+ 49.6
223	+ 2.7	−11.5	+ 31.3
223.1		− 9.5	+ 33.5
224	− 1.9	− 6.9	+ 40.9
224.1		− 5.5	+ 35.3
225	− 3.6	− 2.9	+ 29.9
225.1		− 0.8	+ 32.1
226	− 0.7	+ 1.4	+ 19.6
226.1		+ 0.2	+ 22.8
227	+11.0	− 2.6	+ 58.6
472 (Suita)	+ 5.0	− 0.6	+ 5.1

* Worked out by means of interpolation. † Worked out by means of extrapolation.

Table II.

B. M. No.	1290 Kameoka	1291	1292	1293	1294	1295	1296	1297 Oka	1298	1299	239 Kyoto
H. 1927 − H. 1892	mm 17.0	7.4	16.7	21.6	19.3	8.1	−19.0	−26.3	−23.5	−8.0	mm −9.7

As will be seen from the tables, the first route was laid down in 1885. Since then four re-levellings were made, namely, in 1897, 1899, 1907 and in 1928. The second route was laid down in 1892, and only once re-levelled in 1927. During the above-mentioned years of survey and also in the years 1905 and 1909, some of the bench-marks that were discovered to have lost their original identities in the course of time were promptly restored, while a few were unavoidably removed. In all these surveys, the heights of the bench-marks were measured with reference to B. M. No. 1300 situated in Ootu. While it is difficult to believe that this B. M. suffered no change in height during nearly 40 years, yet in view of the fact that its situation is rather distant from the centres of the earthquakes of 1891, 1909 and 1927, and also that it was one of a dozen consecutive marks which experienced no

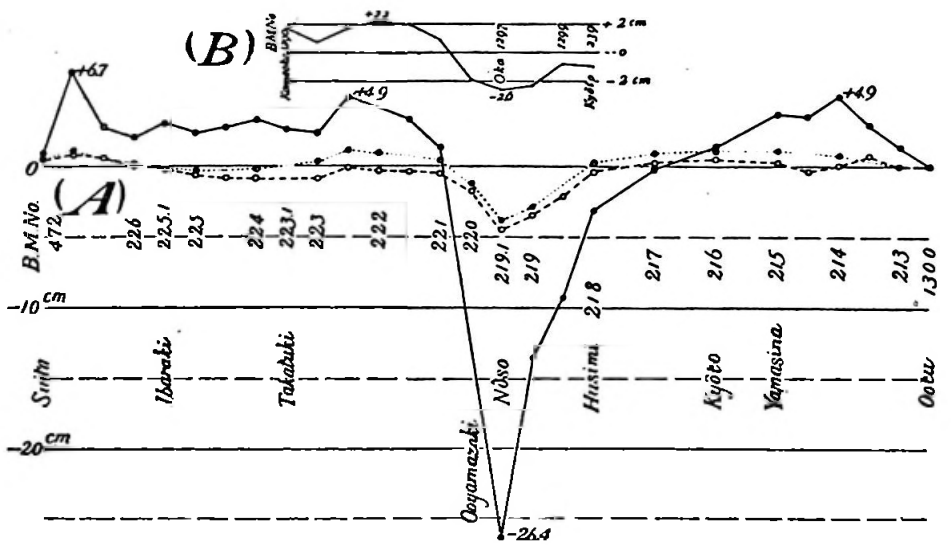

Fig. 2.

greater change than one cm. in the last 30 years, we do not think we have erred to any serious extent in assuming it to have suffered no change in elevation.

Fig. 2, A indicates the changes of land-level undergone by the first-named route, the dotted, the broken and the full lines corresponding to the changes undergone during the 11.2 years interval between 1885 and 1897, the 2.8 years interval between 1897 and 1899 and the 29.0 years interval between 1899 and 1928, respectively. It will be noticed that the changes undergone during the three periods display similar features, each showing a characteristic sag between Husimi and Yamazaki, which goes far to prove the accuracy of our estimates. Further, the change of land-level undergone by the second route, the Kyoto-Kameoka route (Fig. 2, B), during the nearly 35 years interval between 1892 and 1927 shows also a characteristic feature differing little from those shown by the other route, though the change is rather slight. The maximum depression which was as much as 2.6 cm. occurred at B. M. No. 1297, situated at Oka. The maximum elevation which was as much as 2.2 cm. occurred at B. M. No. 1293, situated about midway between Oka and Kameoka. The changes thus far shown, and the geological structure of the district, indicate the presence of three active faults as mentioned in the beginning of this paper. Meanwhile, we shall call the blocks bounded by these lines the Yamazaki and the Yodo-Daigo blocks.

The change of land-level shown by the Suita-Ootu route, however, is much more conspicuous than that shown by the other route. B. M. No. 214, which is situated at the eastern boundary of the Yoko-Daigo block, was elevated as much as 4.9 cm. during the recent 43 years, while B. M. No. 219.1, which is situated at the western boundary of the same block, subsided as much as 26.4 cm. during the same interval of time. This would mean that the block made a tilt dipping westwards with a depression of as much as 31.3 cm. in a distance of about 10 km. The chronic tilting of the block is indeed so conspicuous that the amount of tilt was as much as 8 seconds in the brief interval of 43 years; the most conspicuous ever observed in Japan.

The chronic tilting thus revealed has some important lessons to teach us in the study of the seismicity of the district, past as well as future. During the past 400 years, the locality concerned was visited twice by local destructive earthquakes, the first on Sept. 5, 1596, and the second on Aug. 19, 1830. Husimi received the brunt of the first shock, which caused a loss of 3000 lives in the city, with the destruction of a castle newly built by that famous

historic personage Taiko-Hideyosi; while Kyoto, especially its northern part with its north-western suburbs, severely felt the second shock, resulting in the loss of 280 lives there. This would suggest that the two shocks were associated with the acute tiltings of the block in question; the active centres having migrated, as they have so often done in other regions.

Regarding the question as to whether the chronic tilting now going on portends a future earthquake or not, it is certainly one that deserves our earnest attention. Let us now examine the nature of the topographical change that has been revealed by re-levellings carried on along the Suita-Ootu route. We find indications of a change such as we commonly find associated with faults occurring in an area of compression, and which the writer calls the *N*-shaped fault.[1] It consists of a slight up-bulge of the Yamazaki block on the left and a conspicuous tilting of the Yodo-Daigo block on the right as already noted, the diagrammatic view shown in Fig. 2, A reminding one of the letter *N*. A compressive force from the east

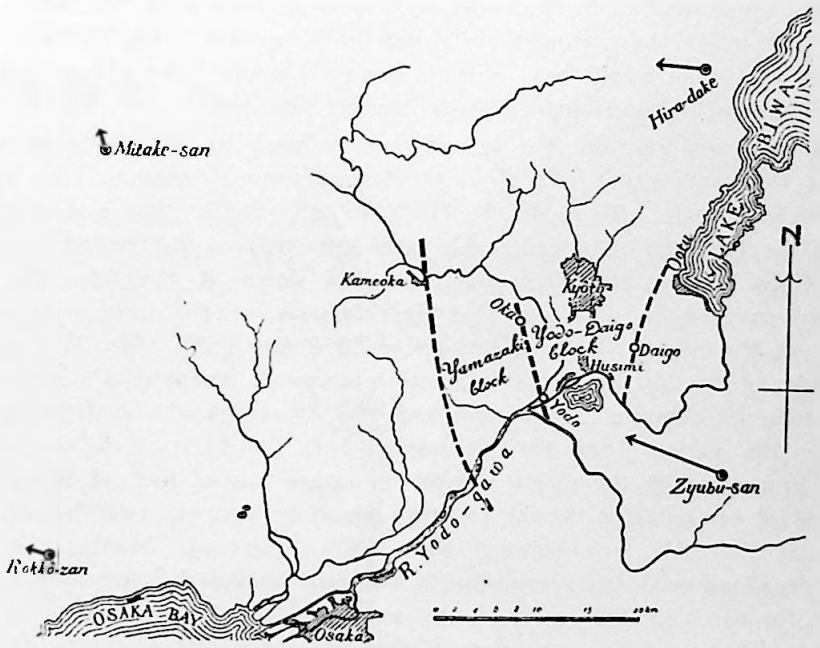

Fig. 3.

(1) Imamura: Publ. Imp. Earthq. Inv. Comm., **25** (1930).

directed to the upper parts of the two block would cause just such a change, although there is no denying that deposits in the river Yodo and vicinity can act as a contributary cause to the dipping of Yodo-Daigo block as we find it.

The view that the blocks in question are being acted upon by compressional force from the east rests on the fact that during the nearly 42 years interval from either 1885 or from 1886 up to 1928, the four first-order triangulation points situated at Hira-dake, Zyubu-san, Mitake-san and Rokkôzan were displaced horizontally as follows (see also Fig. 3):

Hiradake	23.4 cm.	towards N 85°.6 W	(interval 1885–1928)
Zyubusan	50.0 cm.	towards N 67°.5 W	(„ 1886–1928)
Mitakesan	10.3 cm.	towards N 15°.8 W	(„ „)
Rokkôzan	11.9 cm.	towards N 73°.4 W	(„ „)

It will be seen that the country lying between these geodetic points contracted slightly in area, or to be more precise, a linear contraction of about 30 cm. occurred equatorially. If the contraction were uniform over the whole area, each block would have shrunk as much as 5 cm., but I am inclined to the opinion that they would have shrunk to much greater proportions, especially at the lines of discontinuity in the change of land-level.

I shall now examine the subsidences suffered by the different bench-marks, that were situated in the area of maximum depression, i. e. between Husimi and Yodo. These are B. M. Nos. 218, 218.1, 219 and 219.1, of which the first and the third marks were surveyed and re-surveyed completely four times, whereas the others were first laid down at the time the route was re-surveyed in 1897, so that their heights in 1885 have to be worked out from the results of actual surveys of 1885 and 1897. Mr. T. Umemoto, Surveyor of the Military Land Survey Department, computed the said heights on the assumption that the second and the fourth marks both underwent, during the period 1885–1897, a variation in height equal to the mean of those undergone by the marks nearest on either side of each of them. This method of computation should be approximately correct, provided there is no active tectonic line between the marks concerned. While there is no such drawback with the second mark, the same cannot be said of the fourth mark, for the Yodo-Oka active fault crosses the levelling route at a point very close to it. I have therefore worked out the height of the fourth mark by the method of extrapolation, adopting the data given by the nearest two consecutive marks on one side of it. The results thus far obtained give the changes in height as shown in Table III.

Table III.

B. M. No.		218	218.1	219	219.1
		mm	mm	mm	mm
1885–1897	Total	2.2	−13.0	− 28.3	− 38.4
(11.8 y.)	Per annum	0.2	− 1.2	− 2.6	− 3.5
1897–1899	Total	− 5.9	− 7.9	− 5.9	− 6.6
(2.8 y.)	Per annum	− 2.1	− 2.8	− 2.1	− 2.4
1899–1928	Total	−26.6	−72.9	−100.1	−218.9
(29.0 y.)	Per annum	− 0.91	− 2.5	− 3.4	− 7.5

Speaking generally, it will be seen that all the marks suffered subsidences which increased in magnitude with time. The height of B. M. No. 219.1, was measured also in 1905 with reference to B. M. No. 222, situated at Simamoto. In 1907 and in 1909, both of these were measured with reference to B. M. No. 218, situated at Husimi (see Table IV). Simamoto may be

Table IV.

B. M. No.	1899, X-XIII	1905, I-II	1907, VIII-IX	1909, VI	1928, XII
	mm	mm	mm	mm	mm
218 (Husimi)	26807.7		*26807.9	*26807.9	26781.3
218.1	15629.3		15626.7	†15801.3	15747.0
219	15522.5		†16539.4	16507.3	16444.9
219.1 (Noso)	15307.7	15299.8	15299.1	15288.5	15088.8
220	15281.9	15277.8	15276.6		†14330.9
221	13243.4	†14864.7			14886.7
221.1	18821.7	18816.7			18857.6
222 (Simamoto)	9675.7	* 9675.7			†11060.2

* Reference B. M., assumed as unmoved since the preceding survey.
† B. M. restored.

assumed as unchanged during the 5.2 years interval between 1889 and 1905, but Husimi cannot be so treated, so that I have worked out the height of the bench-mark in question referred to the standard mark in Ootu on the assumption that the height of the mark at Husimi varied at a uniform rate

during the period between 1899 and 1928. The changes in height of B. M. No. 219.1 came out as shown in Table V.

Table V.

Period	1885-1897 (11.2 y.)	1897-1899 (2.8 y.)	1899-1905 (5.2 y.)	1905-1907 (2.6 y.)	1907-1909 (1.8 y.)	1909-1928 (19.5 y.)
	mm	mm	mm	mm	mm	mm
Total	−38.4	−6.6	−7.9	−7.8	−12.2	−191.0
Per annum	− 3.5	−2.4	−1.6	−3.0	− 6.8	− 9.8

It will de noticed that from the earlier part of the surveys up to the year 1905, the change was a retardation, but since then conditions have reversed and changed into a gradual and steady increase.

The above-mentioned phenomenon can perhaps be elucidated on the assumption that the seismicity of the district is dependent on that of the district embracing the provinces of Mino, Owari, Etizen, Kaga, Ettyû and Hida, the activities of which culminated in the appearance of a gigantic fault, the so-called *cross-fault*.[1] The two last culminations took place first in 1586 and secondly in 1891. The destructive Husimi earthquake of 1596 took place 10 years after the earlier culmination, while the destructive Anegawa earthquake of 1909 took place 18 years after the later culmination. The seismogenic forces that had been accumulating in the region for some years past broke down, to use a fanciful analogy, the first main frontal line of defences in

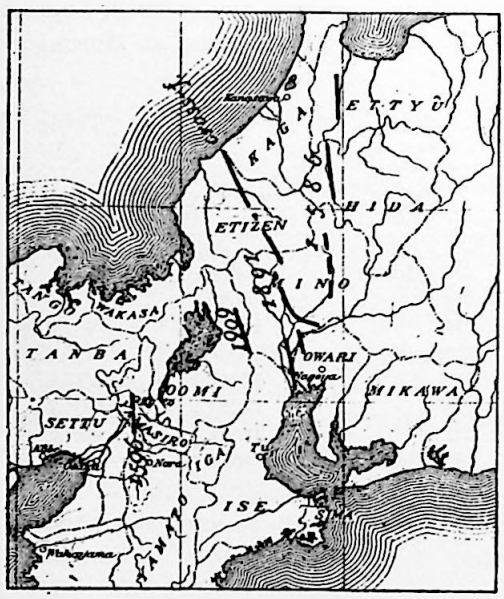

Fig. 4.

(1) Imamura: This Journal, VI, 2 (1928).

1891 and then the second or minor, mid-line of defences in 1909. What then may be the third line of defences? The answer is—Possibly the Yodo-Daigo and the Yamazaki blocks.

Those who can see in the characteristic topographical changes that preceded the Sekihara earthquake of 1927, the Anegawa earthquake of 1909 and the great Kwanto earthquake of 1923,[1] harbingers of these earthquakes, would doubtless find no difficulty, though not perhaps with a little scepticism, in interpreting the present case, as the writer, as a similar phenomenon. In the circumstances, it is highly desirable that investigations on the subject be pushed as far as possible; and with this purpose in mind, the writer submitted the following proposal before a recent meeting of the Earthquake Research Institute:—

(1) Re-levellings of the two above-mentioned routes.

(2) Re-occupying of the second-order triangulation points situated in the area involved. The object of this survey is to investigate the horizontal displacements of the points, and consequently to ascertain the strained features of each mosaic block.

(3) Constant observation of the tiltings of the blocks, especially those of the Yodo-Daigo block.

(4) Observation of the creeping movements, whether horizontal or vertical, which would occur, if there be any, along the lines of discontinuity in the variation of land-level.

(5) Observation, if there be any, of abnormal variations of gravity, as pointed out by Prof. M. Ishimoto and Mr. Z. Tuzi.[2]

The proposal was promptly accepted by the government; a grant necessary for carrying out the above-mentioned investigation having been made to the proposer. One party to carry out the levelling, and two parties for the triangulation have already begun field work. A site for a tiltometer station was selected on Momoyama, a Pleistocene hill near Husimi. Results of work on these preliminaries should be forthcoming within a few months.

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(1) Imamura: Publ. Imp. Earthq. Inv. Comm., **25** (1930).

(2) Ishimoto and Tuzi: Proc. Imp. Acad., **5** (1929) and Bull. Earthq. Res. Inst., **6** (1929).